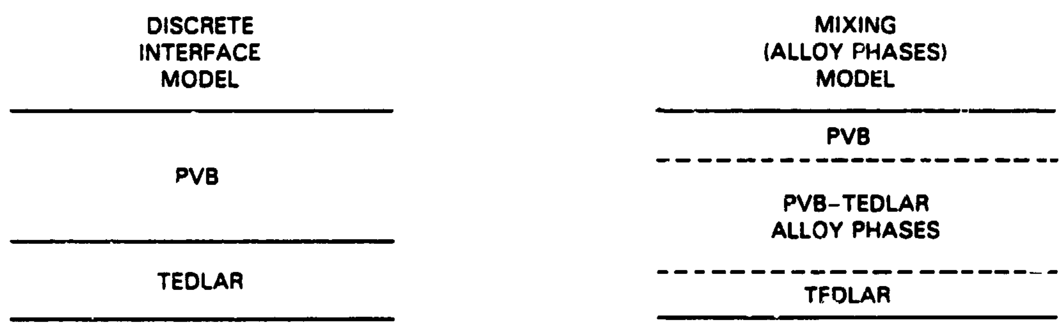
N87-16442

WATER PERMEATION AND ELECTRICAL PROPERTIES OF POTTANTS, BACKINGS, AND POTTANT/BACKING COMPOSITES

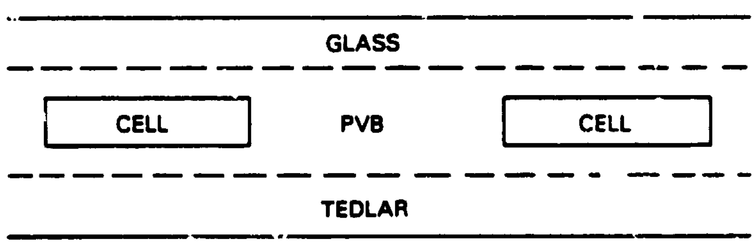
WILKES COLLEGE

J. Orehotsky

Laminates



FOR PATH OF LEAST RESISTANCE IN



Electrical Properties

- Pottants (PVB, EMA, EVA)
- Backing (Tedlar, Mylar)
- Composites (PVB/T, EMA/T, EVA/T)

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Object

To Examine Interfacial Effects
by
Evaluating

- DC Dielectric Constant (K)
- AC Dielectric Constant (K)
- Leakage Resistance (R)

of

Pottants	(PVB, EMA, EVA)
Backing	(Tedlar, Mylar)
Composites	(PVB/T, EMA/T, EVA/T)

Theory

Discrete Interface Model

$$K_{p/b} = \frac{K_p K_b \left[t_p + t_b\right]}{K_p t_b + K_b t_p}$$

$$R_{p/b} = \frac{\rho_p t_p + \rho_b t_b}{A}$$

DC Dielectric Constant by Charge Measurements Before and After Dipole Alignment

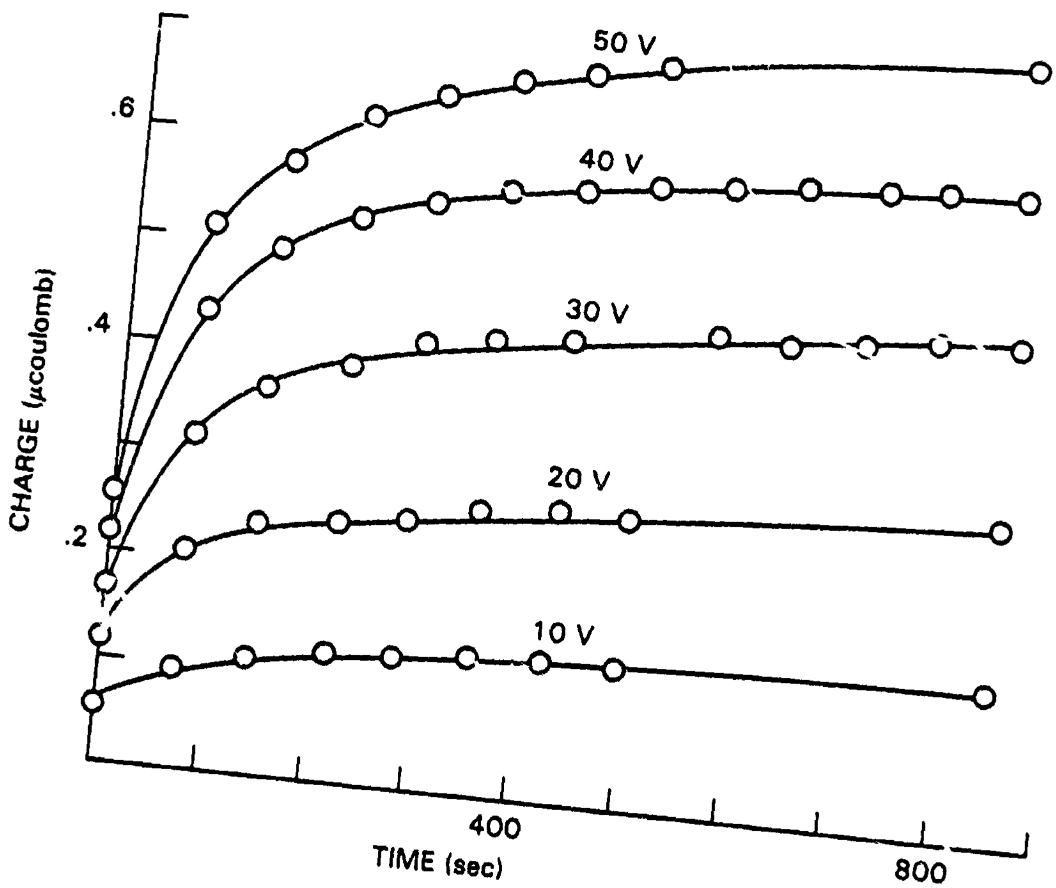
Before:

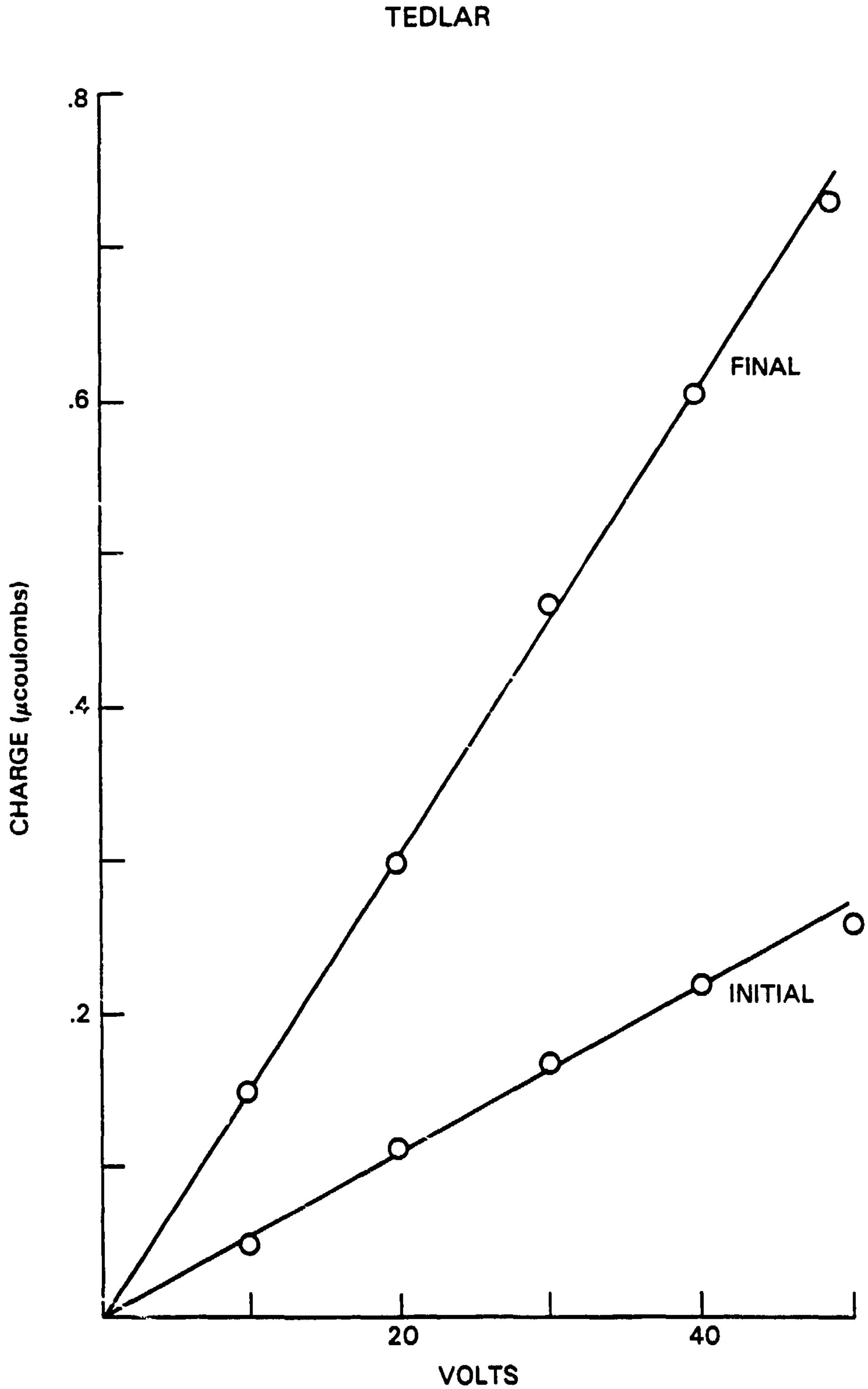
$$K_i = \frac{[dQ_i/dV_A]t}{\epsilon_o A}$$

After:

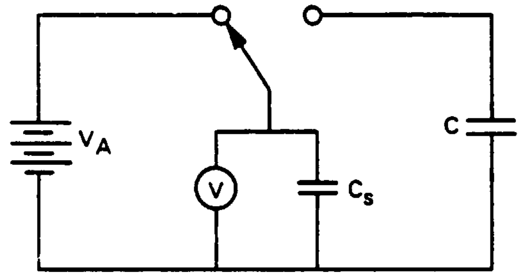
$$K_f = \frac{[dQ_f/dV_A]t}{\epsilon_o A}$$

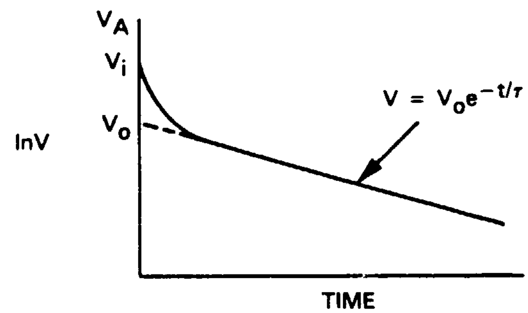
TEDLAR




TEDLAR
.8
.6
.4
.2
CHARGE (μcoulombs)
FINAL
INITIAL
20
40
VOLTS

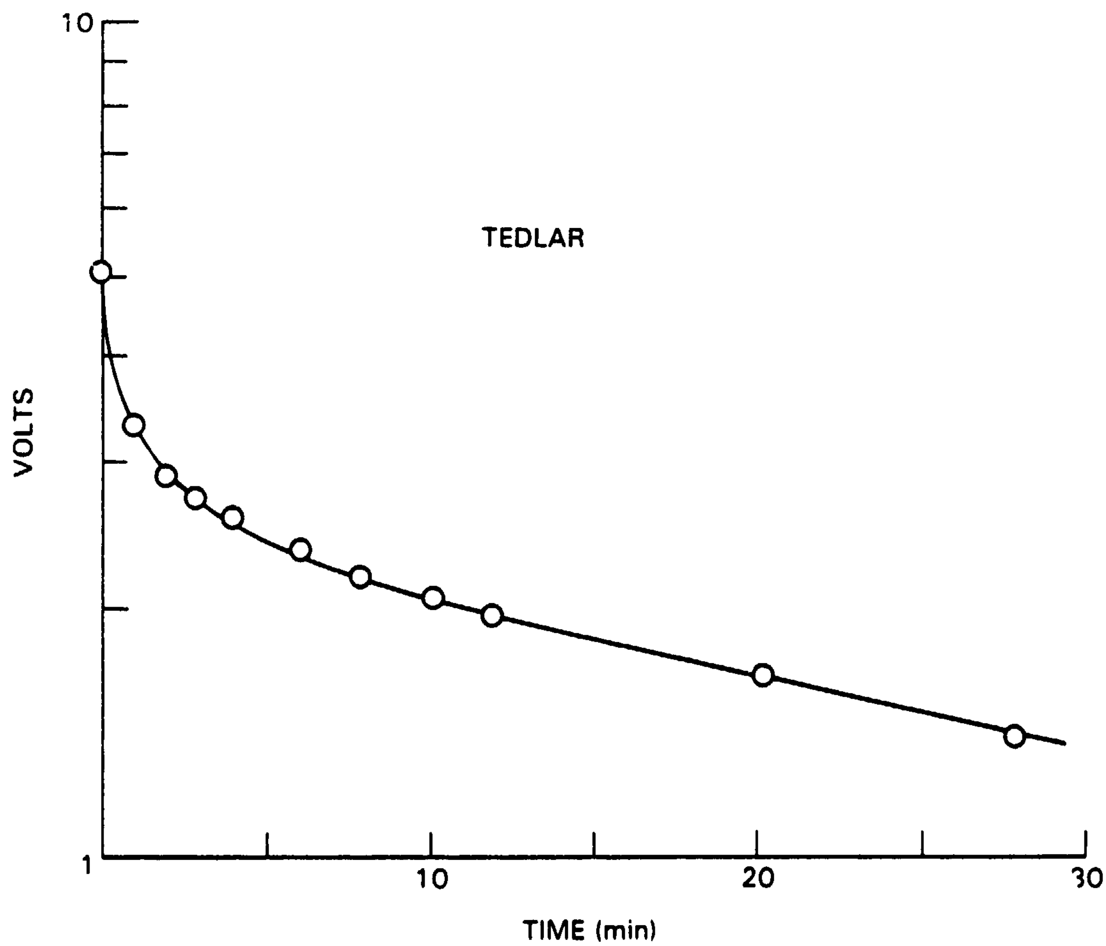
DC Dielectric Constant by Voltage Measurements Using Charge Transfer from Standard Capacitor (C_S)

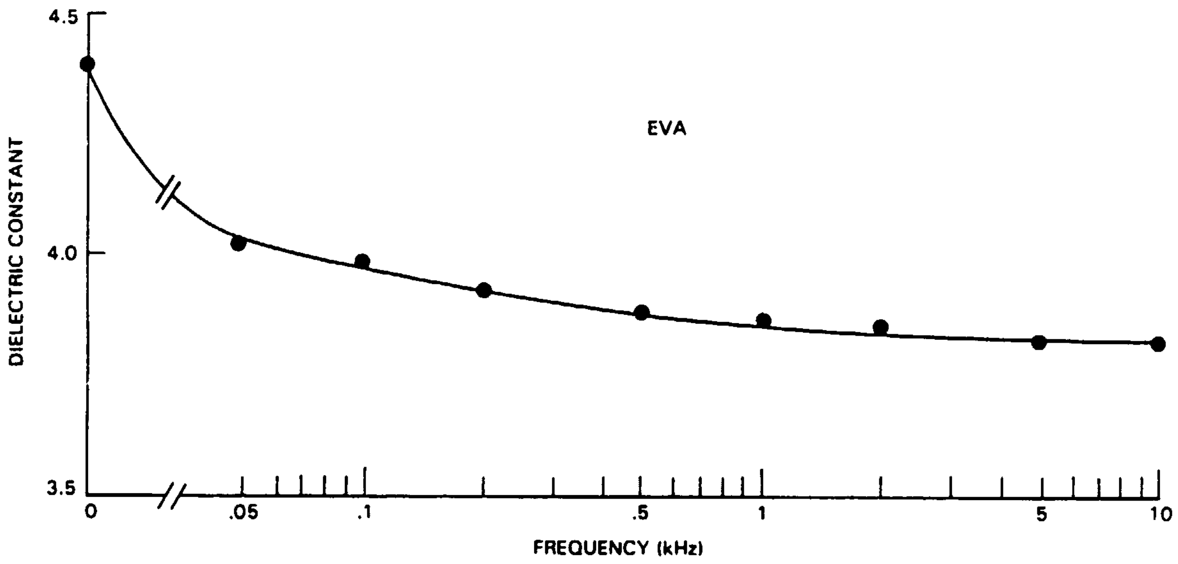




$$K_i = \frac{C_s t}{\epsilon_o A}\left[\frac{V_A - V_i}{V_i}\right]$$

$$K_f = \frac{\tau}{\epsilon_o A}\left[\frac{\tau}{R} \cdot C_s\right]$$





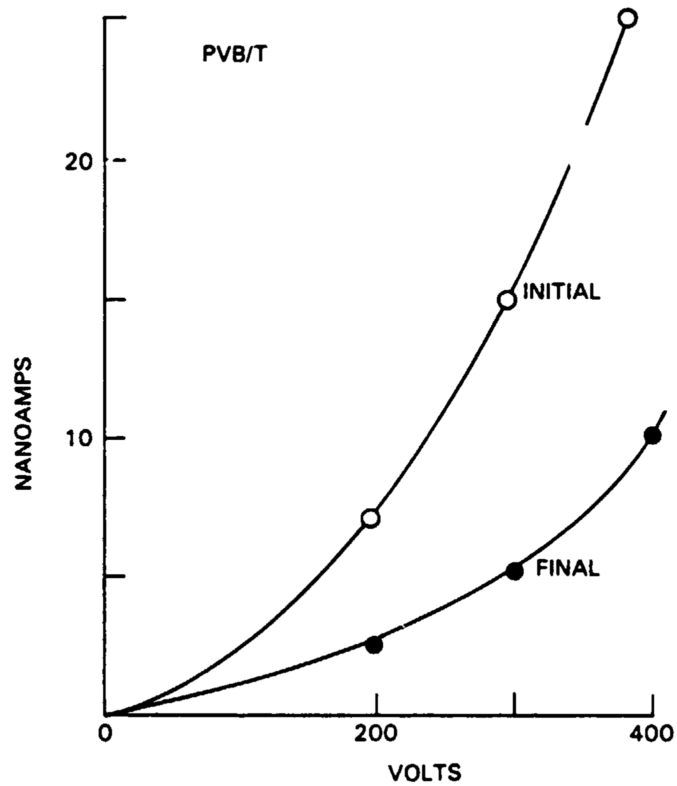
Results

Dielectric Constant

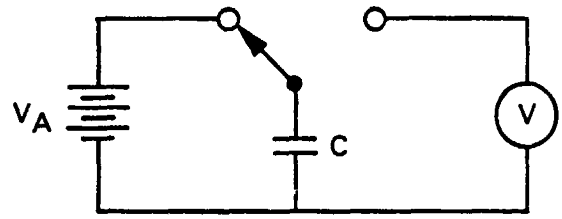
	DC						AC	
	Before			After				
	Q	V	Calc.	Q	V	Calc.	1 kHz	Calc.
PVB	–	6.0		–	8.0		8.7	
EMA	4.3	4.7		4.3	7.1		3.1	
EVA	5.2	4.3		9.4	10.0		3.9	
Tedlar	4.5	4.3		12.7	12.0		3.7	
Mylar	1.3	1.4		–	–		–	
PVB/T	9.1	8.2	5.7	–	–	8.4	4.8	7.3
EMA/T	4.0	3.2	4.3	–	4.7	4.7	3.1	3.1
EVA/T	4.4	4.7	4.7	–	–	9.9	3.7	3.9

Leakage Resistance by Current-Voltage Measurements and Ohm's Law

$$R = dV_A/JI$$

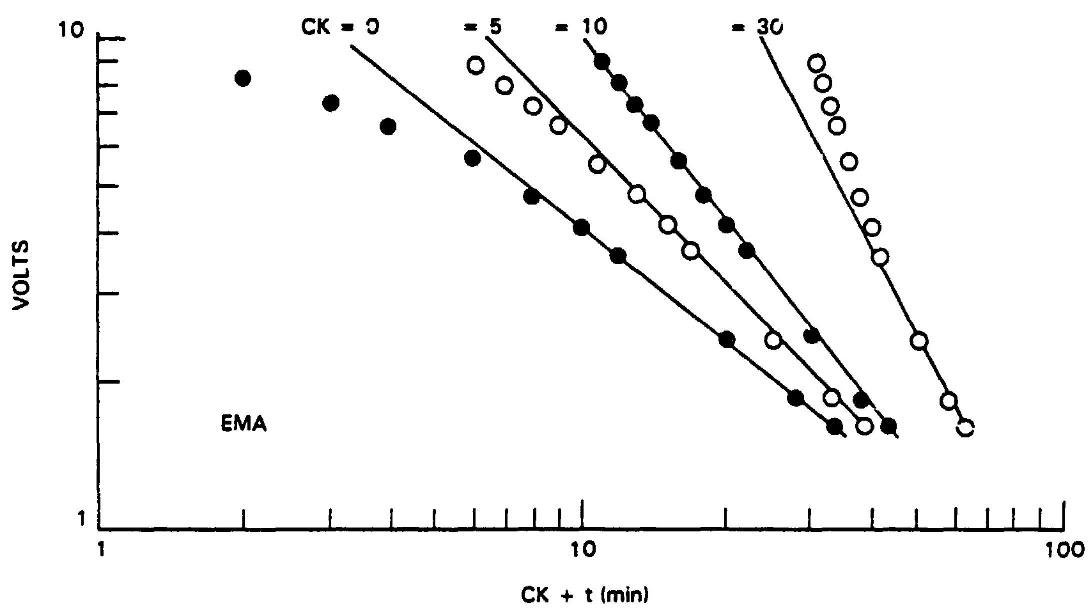


Leakage Resistance by Voltage Decay of a Capacitor



THEORY:

$$V = V_o \, CK^{K/R}[CK + t]^{-K/R}$$



Results: Leakage Resistance (Ω)

	Ohm's Law	Voltage Decay	Calc.
PVB	$1.0(10^{7})$	$0.4(10^{7})$	
EMA	$1.0(10^{12})$	$0.9(10^{12})$	
EVA	$0.4(10^{11})$	$4.6(10^{11})$	
Tedlar	$3.5(10^{11})$	$2.0(10^{11})$	
Mylar	–	$1.4(10^{13})$	
PVB/T	$0.2(10^{12})$	$6.8(10^{9})$	$3.4(10^{12})$
EMA/T	$0.3(10^{13})$	$2.3(10^{13})$	$0.1(10^{13})$
EVA/T	$0.3(10^{12})$	$0.8(10^{12})$	$3.4(10^{12})$

Results: Leakage Resistivities (Ω-m)

PVB	$3(10^7)$
EVA	$5(10^{11})$
EMA	$1(10^{13})$
Tedlar	$4(10^{14})$
Mylar	$2(10^{15})$

Results: Are They Consistent with Discrete Interface Model?

Test	Composite Material		
	EVA/T	EMA/T	PVB/T
DC diel.	Yes	Yes	No
AC diel.	Yes	Yes	No
Resis.	No	Yes	No

Summary

- EMA/T Obeys Discrete Interface Model
- PVB/T Does Not Obey Discrete Interface Model
- Order of Increasing Leakage is Mylar, Tedlar, EMA, EVA, PVB
- Charged Capacitor-Voltage Decay Kinetics Obey Theoretically Predicted Relationship:

$$V = V_0 \, CK^{K/R}[CK + t]^{-K/R}$$

Water Permeation

- Pottants (PVB, EMA, EVA)
- Backing (Tedlar, Mylar)
- Composites (PVB/T, EMA/T, EVA/T)

Object

Theoretically and Experimentally Evaluate

- Temperature Dependence of
  J (water flux)
  and
  P (water permeability)
  in
  Pottants (p) and Backing (b)

- $P_{p/b}$ of p/b Composite in terms of
  P_p and P_b

Theory: Condensation — Self Diffusion — Evaporation Model for Pottants and Backing

- $PT = P_o \exp(-Q_P/RT)$

  $Q_P = 4.6$ Kcal/mole $\begin{pmatrix}\text{water self-diffusion} \\ \text{activation energy}\end{pmatrix}$

- $JT^{6.5} = J_o \exp(-Q_J/RT)$

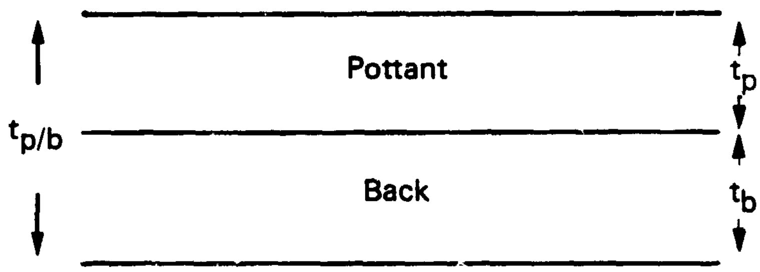
  $Q_J = 4.6 + 9.8 = 14.4$ Kcal/mole

  $\begin{pmatrix}\text{water} & & \text{water heat} \\ \text{self-} & + & \text{of} \\ \text{diffusion} & & \text{vaporization}\end{pmatrix}$

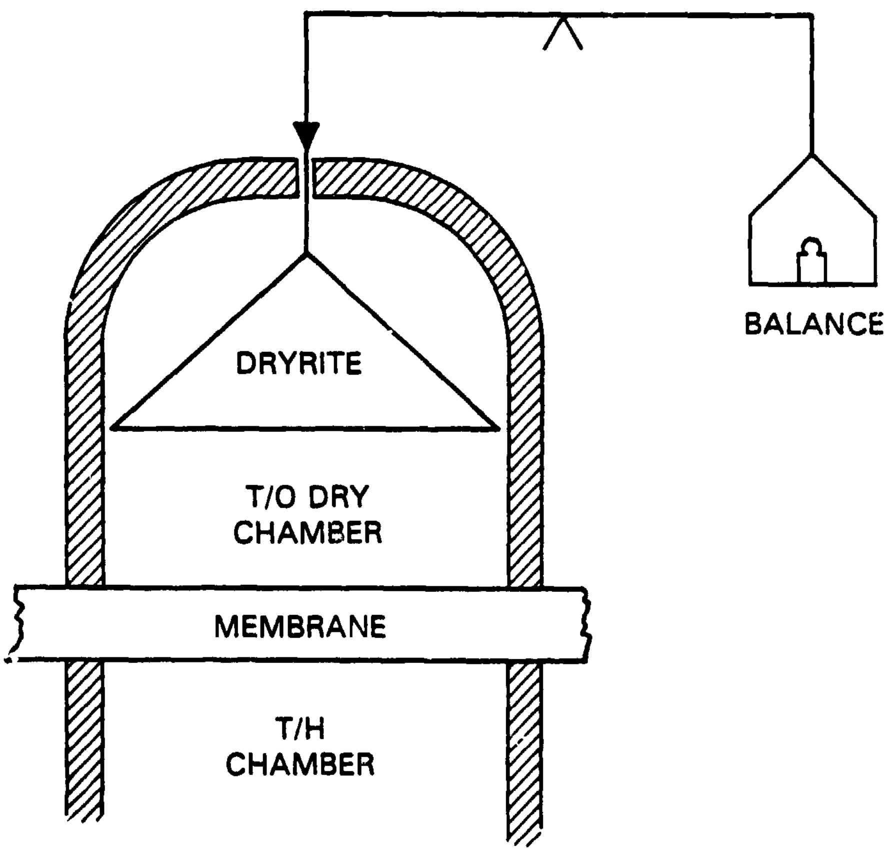
  $J_o \sim S$ (water solubility parameter)

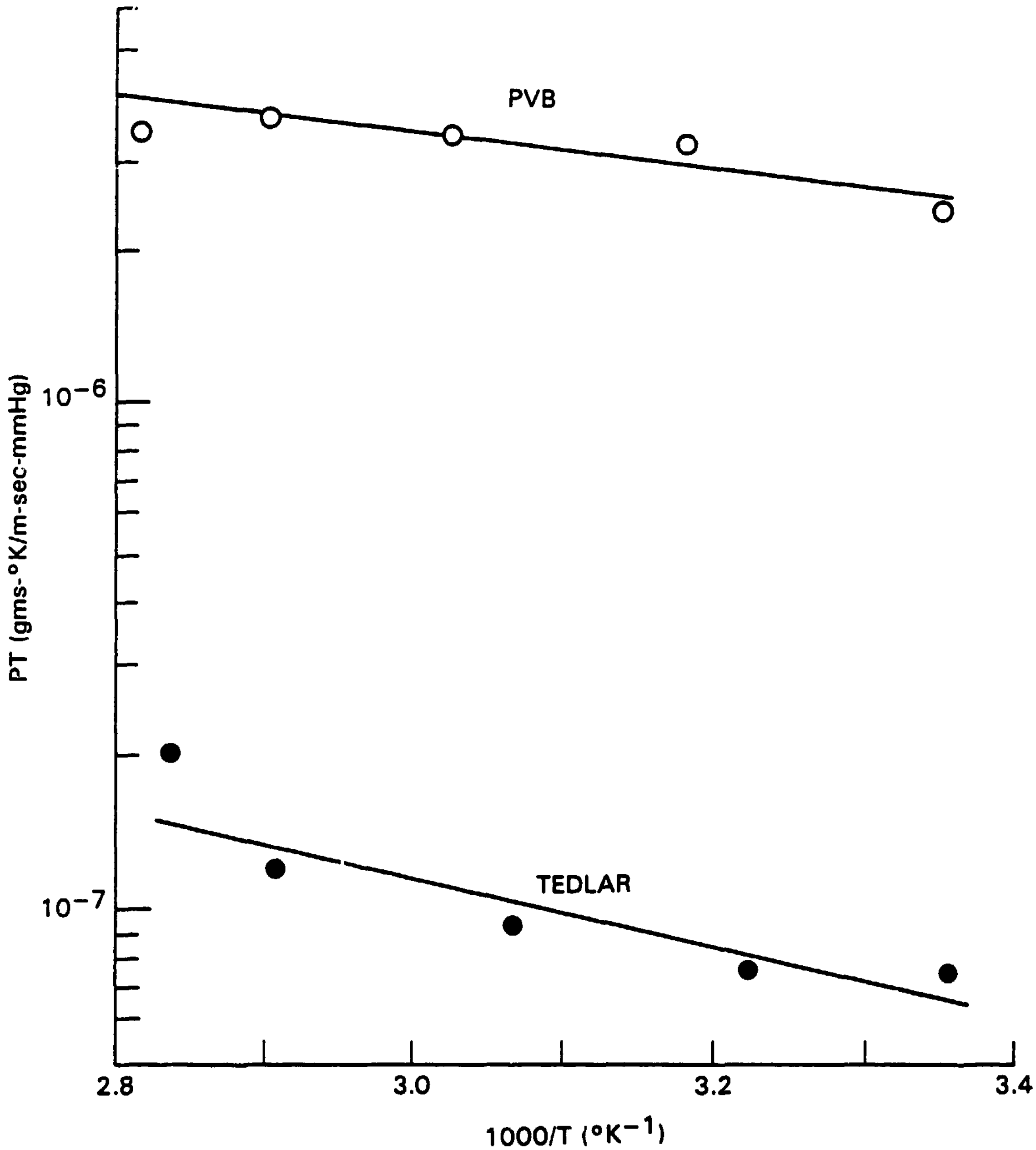
Theory: Discrete Interface Model for Composites (p/b)

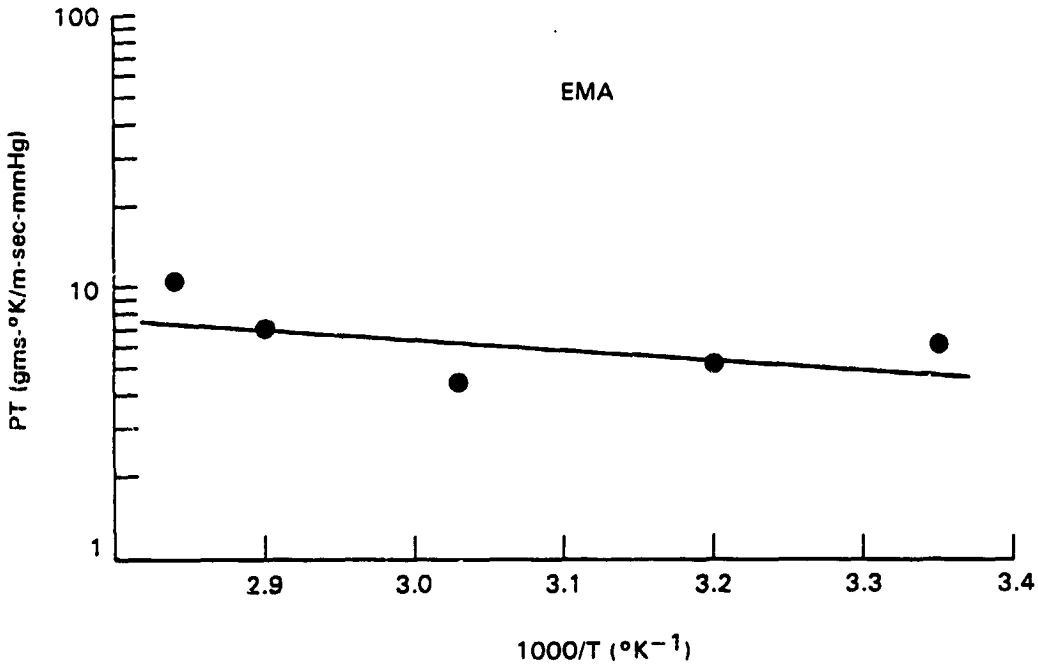
$$P_{p/b} = \frac{t_{p/b}\, P_p\, P_b}{P_p t_b + P_b t_p}$$

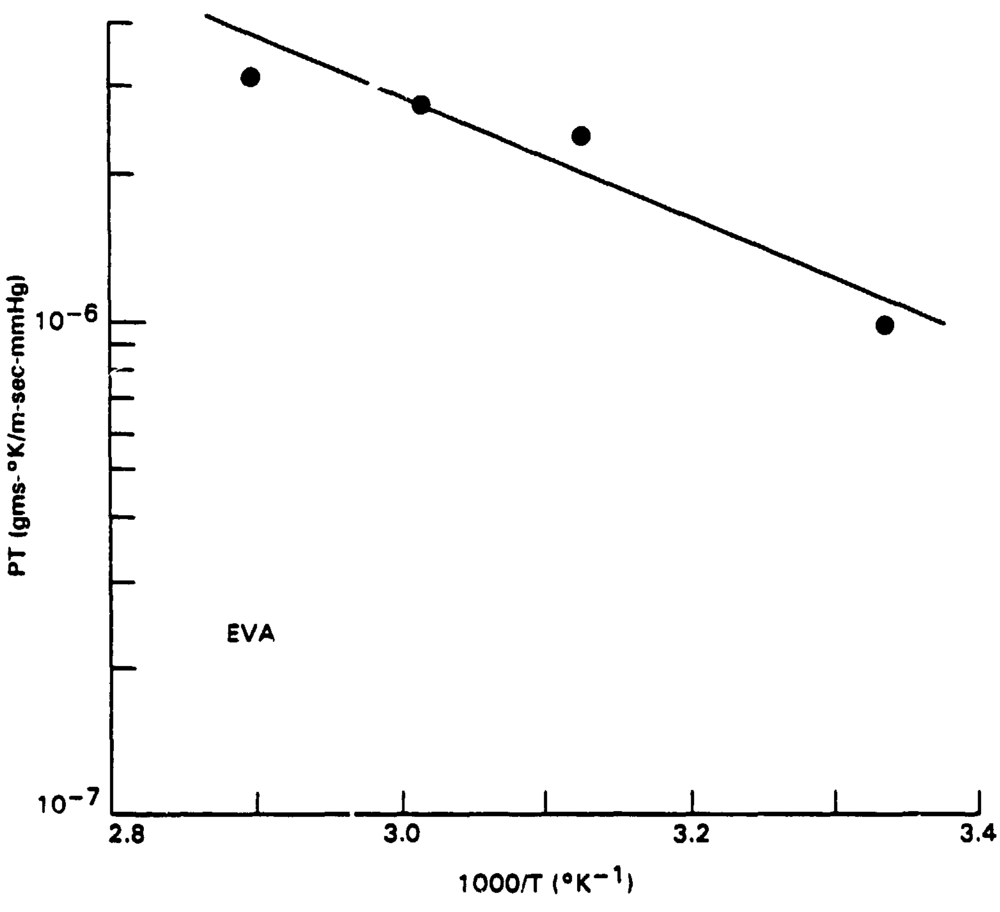


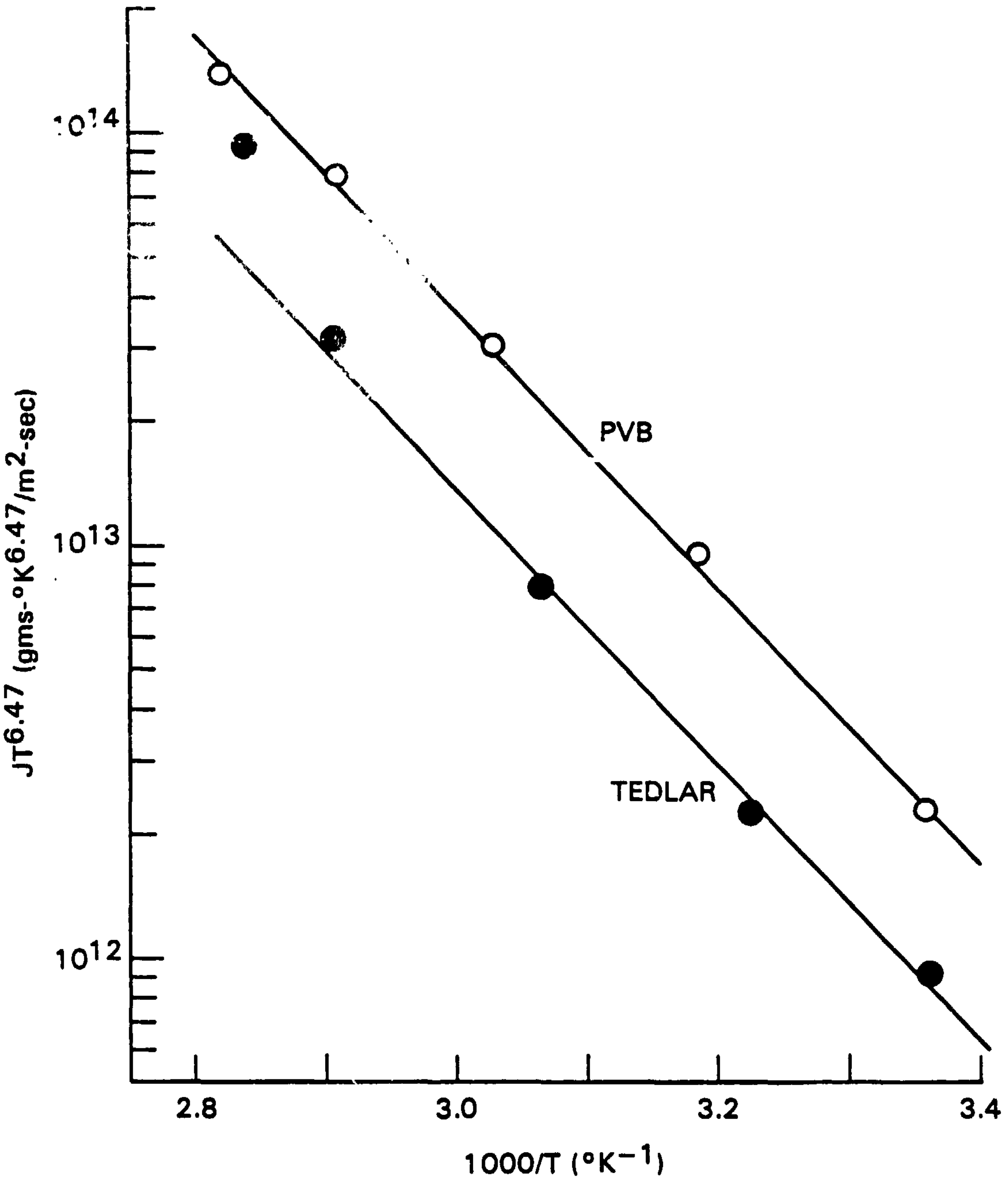
Experimental Arrangement

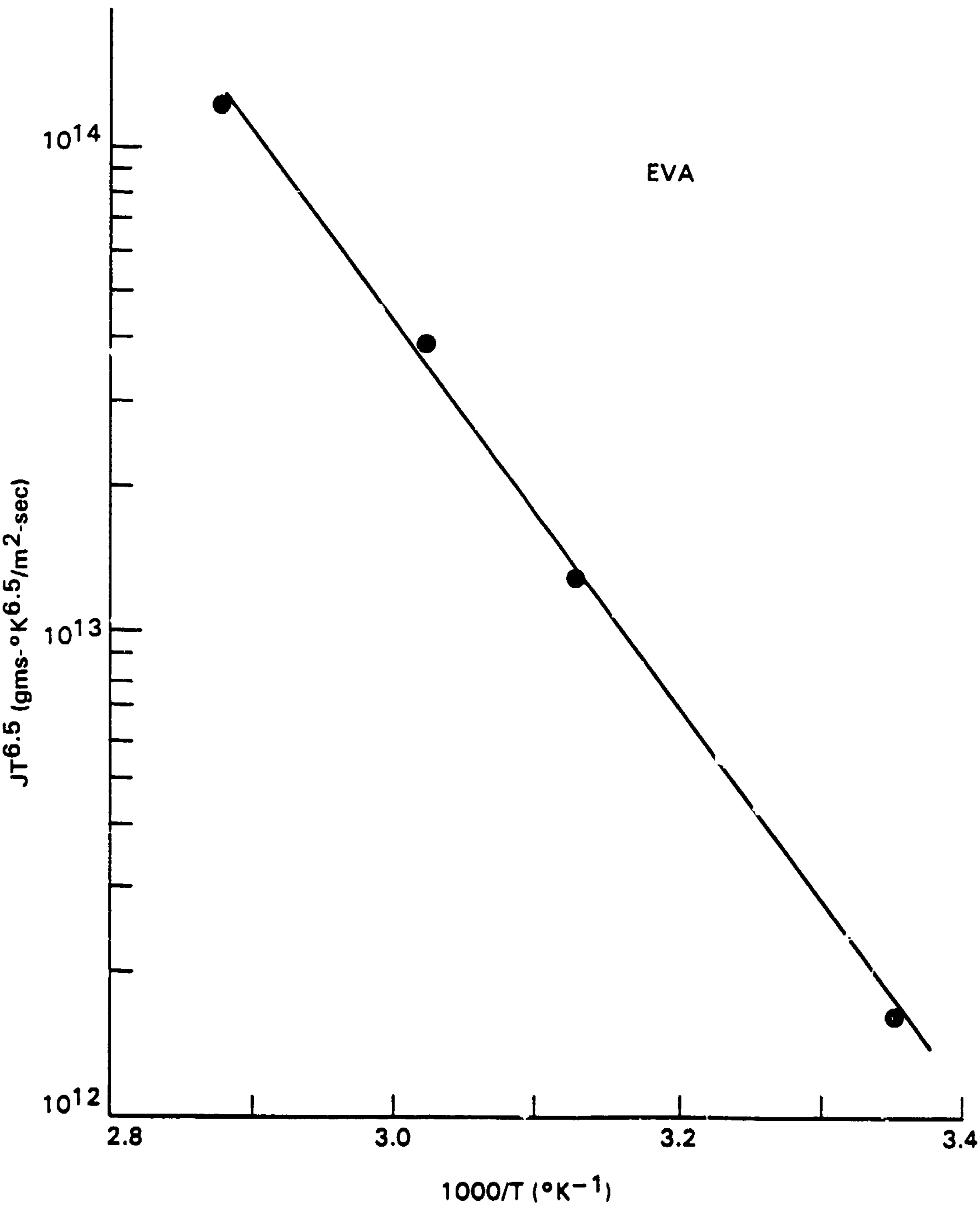


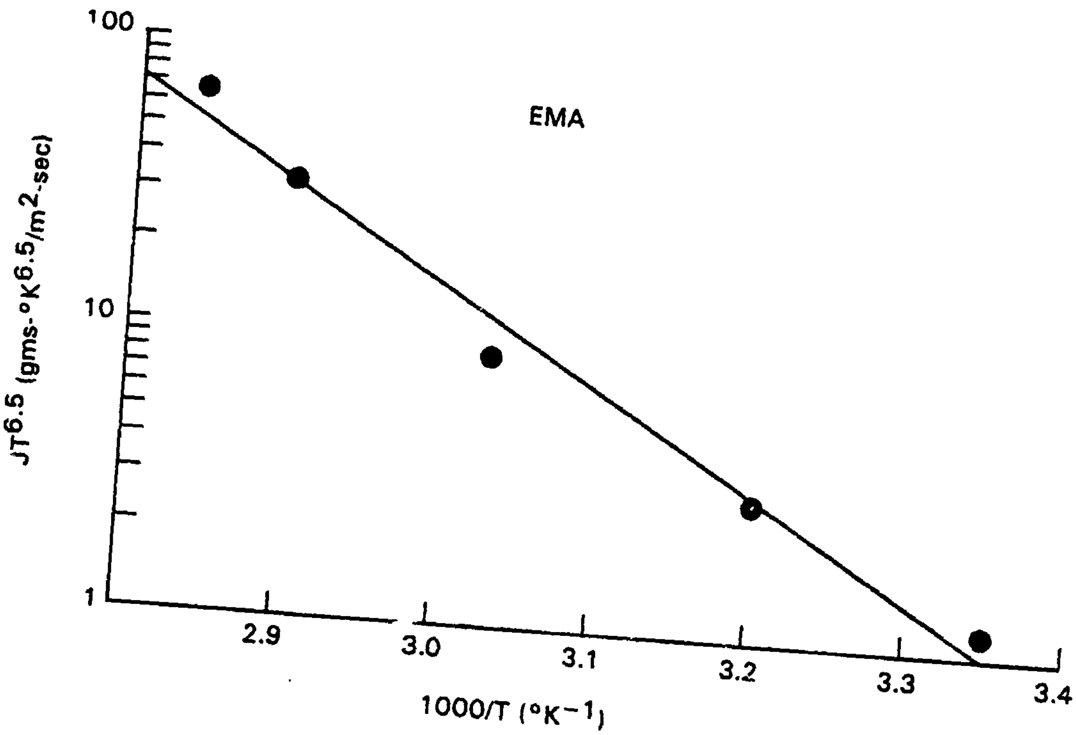

PVB
TEDLAR
10^{-6}
10^{-7}
PT (gms-°K/m-sec-mmHg)
2.8
3.0
3.2
3.4
1000/T (°K^{-1})

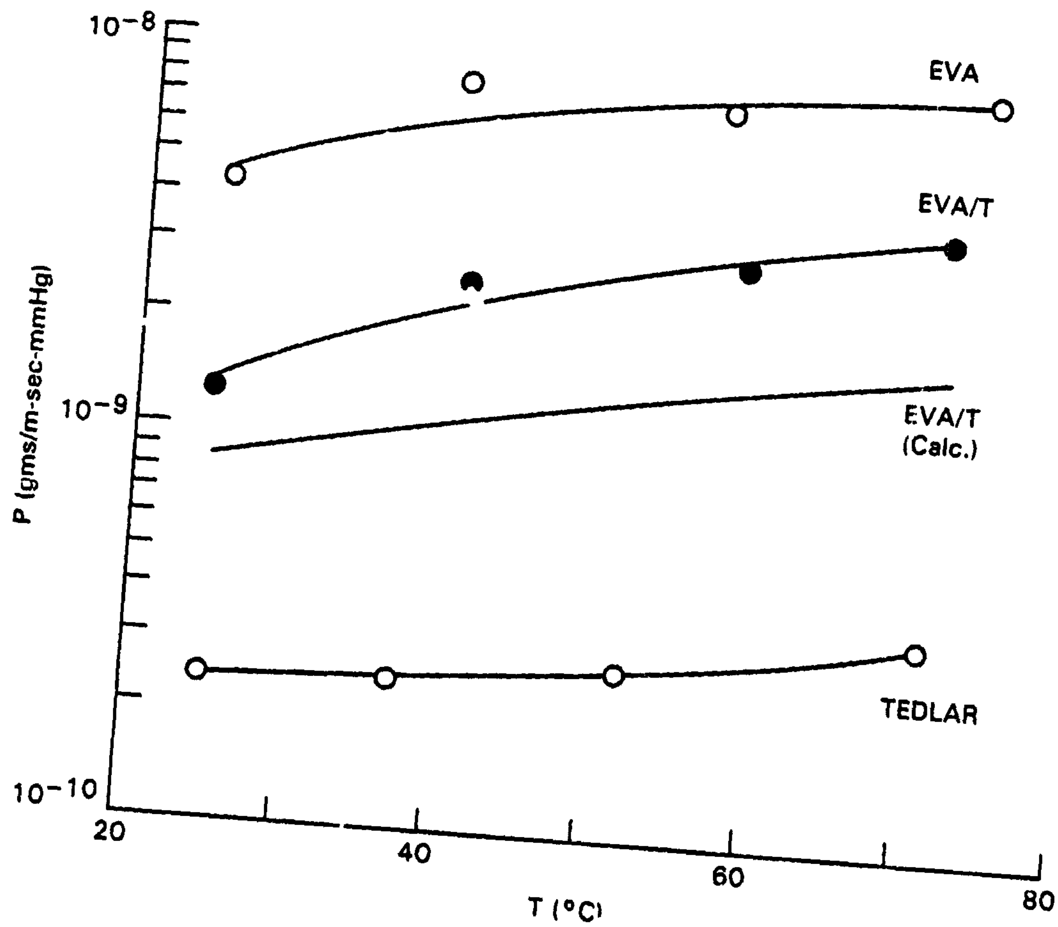

EMA
100
10
1
PT (gms-°K/m-sec-mmHg)
2.9
3.0
3.1
3.2
3.3
3.4
1000/T (°K⁻¹)


EVA
10⁻⁶
10⁻⁷
PT (gms-°K/m-sec-mmHg)
2.8
3.0
3.2
3.4
1000/T (°K⁻¹)


10^14
10^13
10^12
JT^6.47 (gms-°K^6.47/m^2-sec)
PVB
TEDLAR
2.8
3.0
3.2
3.4
1000/T (°K^-1)


EVA
$JT^{6.5}$ (gms-°K$^{6.5}$/m^2-sec)
10^{14}
10^{13}
10^{12}
2.8
3.0
3.2
3.4
1000/T (°K^{-1})


100
10
1
EMA
$JT^{6.5}$ (gms-°$K^{6.5}$/m^2-sec)
2.9
3.0
3.1
3.2
3.3
3.4
1000/T (°K^{-1})


10^{-8}
10^{-9}
10^{-10}
P (gms/m-sec-mmHg)
EVA
EVA/T
EVA/T
(Calc.)
TEDLAR
20
40
60
80
T (°C)

Results

	Activation Energy (Kcal./mole) Q_P	Q_J	Solubility Parameter S
Tedlar	~2.9	15	.614
EMA	~3.1	15	5.2
PVB	~1.4	15	175
EVA	~2.8	18	730
Theoretical	4.6	14.4	—

Results

	Permeability $P \times 10^9$ (gms/m-sec-mmHg)	Thickness $d \times 10^6$ (m)	Resistance $R \times 10^5$ (m^2-sec-mmHg/gm)
Tedlar	0.2	63	3.1
EMA	2.0	480	2.4
EVA	4.0	470	1.2
PVB	8.0	803	1.0

Results

Composites at 25°C

Permeability $P \times 10^9$ (gms/m-sec-mmHg)

	Experimental	Calculated
PVB/T	1.6	1.5
EMA/T	2.0	1.0
EVA/T	1.1	0.8

Conclusions

- $P_T < P_{EMA} < P_{EVA} < P_{PVB}$
- Temperature dependence of J and P for PVB, EMA, and T is consistent with evaporation–self diffusion–condensation model
- P of PVB/T composite is consistent with discrete interface model
- Water solubility: greatest in PVB, least in Tedlar

SILICON MATERIALS

Ralph Lutwack, Chairman

The session on Silicon Materials consisted of two presentations.

JPL reviewed the FSA-sponsored Workshop on Low-Cost Polysilicon for Terrestrial Photovoltaic Solar Cell Applications which was held in Las Vegas, Nevada, October 28-30, 1985.

Union Carbide Corp. (UCC) reported on their development of fluidized-bed reactor technology for producing silicon by the pyrolysis of silane. The technical effort on this program was completed.